spectrum and the solar spectrum taken at Kensington, the silicium line apparently agrees better in position with the less refrangible edge of the solar line than with the middle.

Before this point can be definitely settled, still larger dispersion will have to be employed.

In the paper mentioned, it was shown that silicium made its appearance first at the temperature represented by α Ursæ Minoris, and strengthened at the higher temperature of α Cygni and β Orionis, afterwards weakening as we pass through the still higher temperatures of ζ Tauri and γ Orionis, until at the ζ Orionis stage it is bordering on extinction.

In the same paper the behaviour of a line at λ 4089·2 was plotted, and at the same time it was quoted as an "unknown" line.

It is interesting to note that this line is now traced to silicium, and is the strongest line in set B. It is apparently a short-lived line in stellar spectra, as it only occurs between the stages of temperature represented by γ Orionis and ζ Orionis, being one of the weakest lines in the spectrum of the former star, and one of the strongest in that of the latter.

Most of the photographs of the silicium spectrum under varying conditions were taken by Mr. Butler. The wave-lengths of the lines have been reduced by Mr. Baxandall, and he is also responsible for establishing the identity of the terrestrial and the stellar lines. My thanks are due to him also for help in the preparation of the present communication.

Preliminary Table of Wave-lengths of Enhanced Lines." By Sir NORMAN LOCKYER, K.C.B., F.R.S. Received November 9, —Read November 23, 1899.

Introduction.

In the year 1881 I communicated a paper* to the Royal Society in which I described some experiments relating to the brightening of some lines in the spectrum of iron on passing from the arc to the spark.

It was found that in the case of iron, the two lines in the visible spectrum at λ 4924·1 and λ 5018·6, on Rowland's scale, were greatly enhanced in brightness, and were very important in solar phenomena.

The work was subsequently carried into the photographic region of the spectrum with very interesting results, since it was found that several other lines were enhanced at the highest temperature I could then obtain.

In a later paper† I described the results obtained in further photo-

* 'Roy. Soc. Proc.,' 1881, vol. 32, p. 204.
† 'Roy. Soc. Proc.,' vol. 61, p. 158.

graphic investigations of metals at high temperatures, dealing specially with the spectra of iron, calcium, and magnesium, and more recently still,* I referred to the enhanced lines of other substances, but refrained from giving a list of the wave-lengths of the lines photographed, as the series of comparisons with the large Rowland grating was not then completed.

The important part which the enhanced lines of the elements play in the study of stellar spectra cannot be over-estimated, but a great advance can only be made in this direction by a systematic examination of the spectra of all the elements. Such an undertaking as this involves considerable time and labour. I have been fortunate enough to have the use of the large 42-inch Spottiswoode coil for a short space of time, and employed it in this work, for which it is specially adapted, as the brilliancy of its spark shortens the time of exposure. Although I have previously stated my indebtedness to Mr. Hugh Spottiswoode and Mr. G. Matthey for their assistance, I wish again to express my best thanks to them, and I must now add Professor Moissan and Sir William Crookes, who have kindly supplied me with some specimens of metals.

The elements which have been dealt with in this investigation are the following :—" Aluminium, bismuth, chromium, copper, iron, magnesium, manganese, titanium, and vanadium."

For each of these elements the spark and arc spectra were photographed and compared, and the wave-lengths of the enhanced lines, that is, those lines which are intensified in passing from the temperature of the electric arc to that of the spark, were determined.

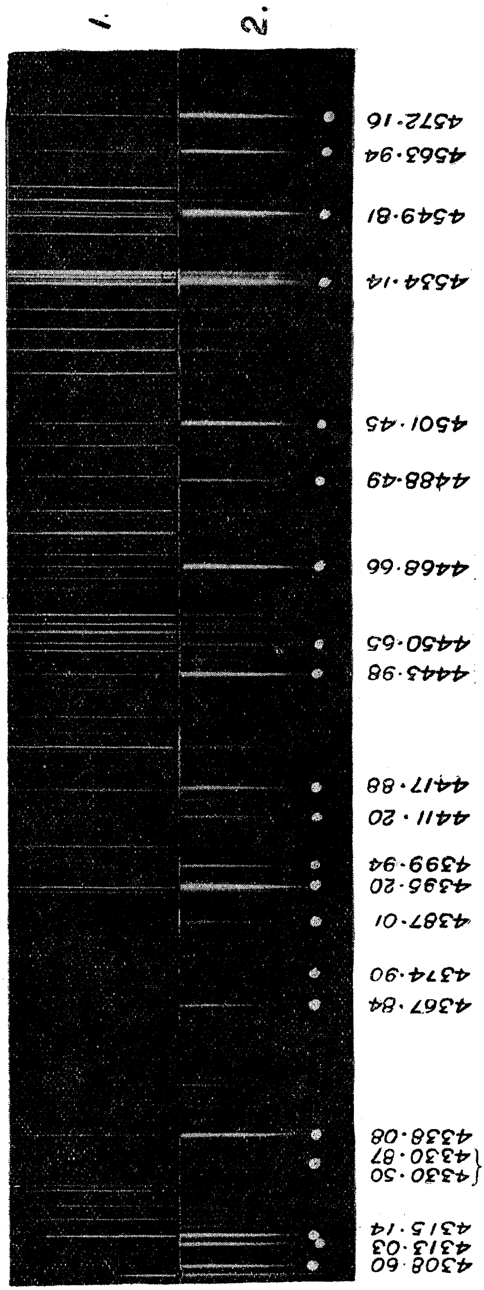
Method of Reduction.

The method of reduction was as follows :—The spark spectrum of the element was first compared directly with the spark spectrum of air between platinum poles, and the air lines were thus eliminated. The spark and arc spectra of the element being taken on different plates, were then compared, and the lines present in the spark spectrum but absent from the arc, or lines relatively more intense in the spark than in the arc spectrum, were noted. The wave-lengths of these lines were then determined by direct comparison with a solar spectrum taken under the same instrumental conditions, and reference to Rowland's list of lines in the normal solar spectrum.

Instruments Employed.

The grating used is a 6-inch concave one, having a surface 2 inches by $5\frac{3}{4}$ inches, ruled with 14,438 lines to the inch, and a radius of curvature of 21 feet $8\frac{1}{2}$ inches. The instrument is mounted in the

* 'Roy. Soc. Proc.,' vol. 61, p. 441.



Titanium.—Enhanced Lines.
1. Arc. 2. Spark.

manner described by Rowland, the camera and grating being at opposite ends of an iron girder adjusted exactly to the radius of curvature of the grating. It has been found that by carefully making the adjustment the scale can be maintained constant within a very small limit, and the conditions were such that it was possible to use plates 18 inches long without bending.

In some cases a Steinheil prism spectroscope was used. The dispersion arrangement of this instrument consists of four dense flint prisms, three of 45° angle and one of 60°. These are fed by a collimator of $1\frac{1}{2}$ inches aperture and $18\frac{1}{2}$ inches focal length. The camera objective is a single quartz lens of 2 inches aperture and about 54 inches focal length (for λ 4340), the non-achromatism of which necessitates a considerable inclination of the photographic plate to the axis of the lens. The total deviation for the blue region of the spectrum is about 150°. The scale of the spectrum is as follows:—

$$\text{D—F} = 2\tfrac{7}{8} \text{ inches.}$$

$$\text{F—K} = 6\tfrac{7}{8} \quad \text{,,}$$

The spark conditions were as follows:—The Spottiswoode coil is capable of giving a spark 42 inches long in air. For spectroscopic purposes, however, a condenser is inserted in parallel with the secondary circuit, the length of spark then obtainable depending on the capacity of the particular condenser used. These have varied from a single gallon jar to a battery of twelve jars of about 15 gallons each, and finally a plate condenser has been used, at the suggestion of Professor Boys.

This consists of thirty sheets of plate glass, 30 inches by 25 inches, with tinfoil, 24 inches by 12 inches, between each pair. The spark under these conditions varies from about 25 to 2 mm. in length, and this was again further controlled in intensity and duration by a secondary spark gap in series with the one containing the metallic poles.

The primary was fed from the street circuit at 100 volts, the usual current employed being about 25 amperes. Interruption of the current in the primary was by means of a mercury break actuated by hand.

In the case of the arc, the exposures lasted generally for about fifteen minutes, while an hour and a quarter was the average time given for the spark.

My thanks are due to Mr. C. P. Butler, who was employed in taking the photographs, to Mr. F. E. Baxandall, who is responsible for their discussion, and to Dr. Lockyer for assistance in the preparation of this note. The enlargement of portions of the arc and spark spectra of titanium was made by Sapper J. P. Wilkie, R.E.

The Tables.

In the following tables, in which the elements are arranged alphabetically, will be found the wave-lengths of all those lines which have been observed as enhanced in the region examined.

The first column gives the wave-lengths of the enhanced lines, the second and third their intensities in the spark and arc respectively (maximum intensity = 10), and the fourth column is devoted to remarks.

In the case of iron and copper I give in addition the wave-lengths of the spark lines obtained by Herren Exner and Haschek* and Eder and Valenta respectively.†

Aluminium.

λ.	Int. in spark.	Int. in arc.	Remarks.
3900·68	5	0	Enhanced line of Ti at λ 3900·68.
4480·00	6	0	
4513·20	9	0	
4529·80	10	0	Enhanced line of Ti at λ 4529·6.
4663·70	10	0	

Bismuth.‡

λ.	Int. in spark.	Int. in arc.	Remarks.
3846·1	3	0	
3849·3	5	0	
3864·5	8	0	
4079·3	8	0	
4081·6	2	0	
4245·3	3	0	
4259·8	10	0	
4272·6	3	0	
4302·4	9	0	Enhanced Ti line at λ 4302·09.
4308·8	2—3	0	,, ,, λ 4308·60.
4328·6	5	0	
4340·7	5	0	
4387·0	3	0	Enhanced Ti line at λ 4387·01.
4391·6	3	0	

* W. Marshall Watts, 'Index of Spectra,' Appendix J, p. 2.

† *Ibid.*, Appendix H, p. 38.

‡ The wave-lengths are only given to five figures, as greater accuracy cannot be obtained owing to the great breadth and fuzziness of the lines.

Chromium.

λ.	Int. in spark.	Int. in arc.	Remarks.
4038·20	2	0	
4242·62	3	trace	
4262·14	2	0	
4284·38	1	0	
4558·83	4	2	
4588·38	4	1	
4592·50	trace	0	
4619·71	1—2	trace	
4634·25	?	1	Intensity in spark difficult to determine owing to superposition of an air line.

Copper.

λ. Lockyer.	Int. in spark.	Int. in arc.	λ. Eder and Valenta.	Int. in spark.	Remarks.
4545·1*	2	0			
4556·10	5	0	4555·94	1*n*	Enhanced line of Fe at λ 4556·10.

* Seen only in spectrum taken with 4-prism Steinheil spectroscope.

Iron.

λ. Lockyer.	Int. in spark.	Int. in arc.	λ. Exner and Haschek.	Int. in spark.	Remarks.
3839·78	2—3	0	3839·87	2	
3846·55	2—3	1	3846·54	2	
3863·87	3	1—2	3863·86	1	
3871·86	4	1—2	3871·88	3	
3906·04	1	0	3906·2	1*n*	Si spark line at λ 3905·70.
3935·92	5	4	3935·90	2	
3939·28	1—2	0	3939·06	1*n*	
4002·77	1—2	trace	4002·75	1	
4048·82	3—4	2	4049·03	1*n*	
4055·63	3	2	4055·58	1	
4173·52	3	1—2	4173·59	2	Enhanced line of Ti at λ 4173·70.
4178·95	3—4	trace	4179·01	2	
4233·25	4—5	0	4233·26	4	
4296·65	2	0	4296·73	1	
4302·35	2—3	2	4302·32	1	Enhanced line of Ti at λ 4302·09.
4351·93	5	0	4351·89	2	
4385·55	3—4	trace	4385·55	1	
4451·75	3	2	4451·70	1*n*	
4462·30	2	0	4462·15	1*n*	
4489·35	1	0	4489·34	1*n*	
4491·57	2	0	4491·58	1	
4508·46	5	trace	4508·42	2	
4515·51	4	,,	4515·49	1	
4520·40	3	1	4520·41	1	
4522·69	6	2	4522·80	2	
4541·40	3	1	4541·68	1	
4549·64	7	1	4549·65	3	Enhanced line of Ti at λ 4549·81.
4556·10	5	0	4556·04	1	,, ,, Cu at λ 4556·10.
4576·51	1	0	4576·48	1	
4584·02	8	1	4584·01	4	
4629·60	4	0	4629·51	1	
4635·40	3	0	4635·50	1*n*	
*4924·11	8	0	..	..	Exner and Haschek's observations do not extend to this region.
*5018·63	7	1	..	..	
*5169·07 *5169·22	6	2	..	..	
*5316·79	3	0	..	..	

* Reduced from photograph taken with two 6-inch objective prisms.

*Magnesium.**

λ.	Int. in spark.	Int. in arc.	Remarks.
4395·0	1	0	Enhanced line of Ti at λ 4395·20.
4481·3	10	0	

Manganese.

λ.	Int. in spark.	Int. in arc.	Remarks.
4000·20	2	0	
4105·05	3	0	
4128·36	2—3	trace	Strong Si spark line at λ 4128·1.
4137·16	3—4	0	
4200·40	2	0	
4206·56	4	0	
4242·45	4	0	
4244·43	1—2	0	
4248·10	1	0	
4251·86	5	0	
4253·13	5	0	
4259·35	4	0	
4292·35	2—3	0	
4300·37	2	0	Enhanced line of Ti at λ 4300·21.
4326·82	5	0	
4344·19	8	0	Enhanced line of Ti at λ 4344·45.
4348·62	2	0	
4365·50	1—2	0	
4478·86	2—3	0	

* The wave-lengths are only given to five figures, as greater accuracy cannot be obtained owing to the broad and fluffy nature of the lines.

Titanium.

λ.	Int. in spark.	Int. in arc.	Remarks.
3900·68	10	4	
3913·61	10	4	
3932·16	4	trace	
3987·75	1	0	
4012·54	5	1	
4025·29	3	1	
4028·50	6	1	
4053·98	5	trace	Enhanced line of V at λ 4053·80.
4055·19	2	1	
4161·70	2—3	0	
4163·82	10	2	
4172·07	10	1	
4173·70	3	0	Enhanced line of Fe at λ 4173·52.
4174·20	2	0	
4184·40	1	0	
4227·40	2	0	
4290·38	6	2	
4294·20	7	3	
4300·21	6	1—2	
4302·09	3	1—2	Enhanced line of Fe at λ 4302·35.
4308·60	7	1—2	
4313·03	7	1—2	
4315·14	8	1	
4316·96	2	0	
4321·20	3	1	
4330·50	2	trace	
4330·87	2	,,	
4338·08	8	4	
4341·53	3	1	
4344·45	3	1	Enhanced line of Mn at λ 4344·19.
4351·00	2	0	
4367·84	5	1	
4374·90	3	0	
4387·01	5	trace	
4391·19	1—2	,,	
4395·20	9	5	Enhanced line of Mg at λ 4395·0.
4396·01	2	trace	
4399·94	7	3	
4411·20	5	trace	
4417·88	6	2	
4421·93	3	2	
4443·98	9	4	
4450·65	3	1	
4464·62	3	1	
4468·66	9	4	
4488·49	5	1	
4501·45	8	4	
4529·60	3	trace	
4534·14	5	2	
4549·81	8	4	Enhanced line of Fe at λ 4549·64.
4563·94	7	3	
4572·16	9	4	
4590·13	3	1—2	

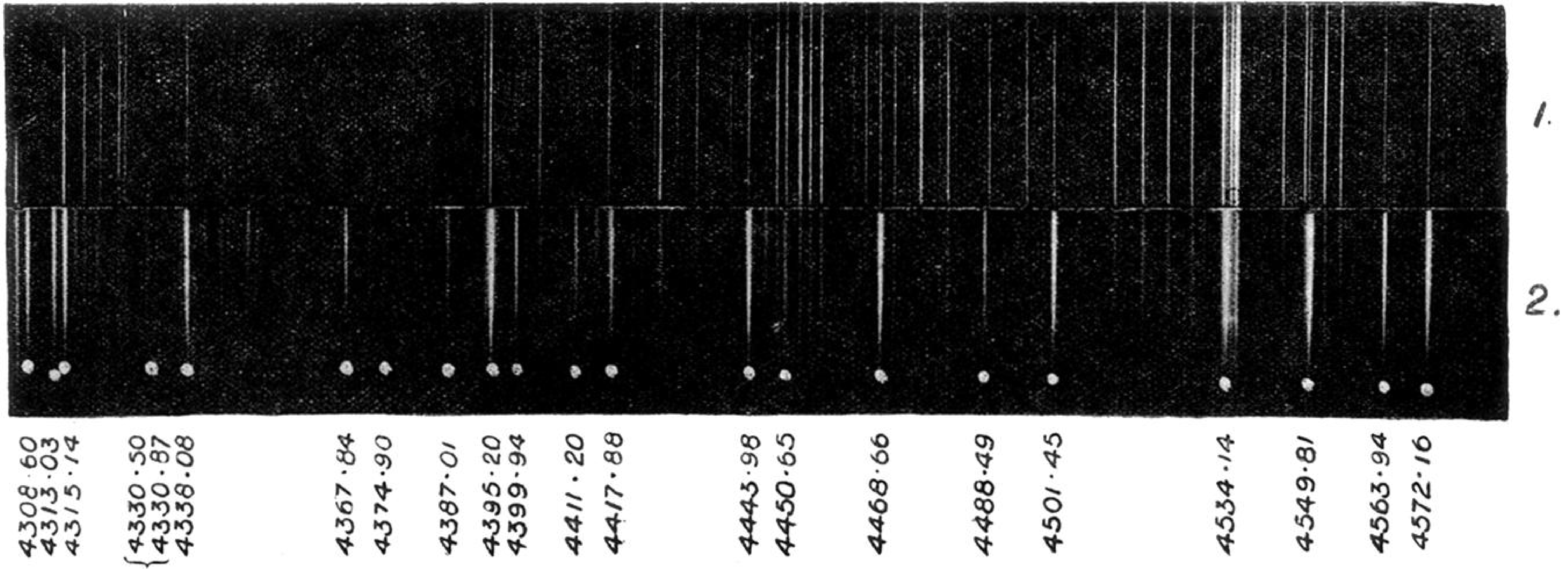
Vanadium.

λ.	Int. in spark.	Int. in arc.	Remarks.
3827·30	2—3	trace	
3867·00	3	2	
3878·90	8	4	
3885·05	3	2	
3899·30	6	3	
3903·40	6	4	
3914·44	6	4	
3916·50	6	4	
3952·07	7	5	
3973·85	5	4	
3985·90	1	0	
3997·30	5	4	
3999·30	2	0	
4005·85	10	7	
4017·00 } 4017·40 }	1	0	
4023·60	9	7	
4035·80	8	6	
4053·80	2—3	trace	Enhanced Ti line at λ 4053·98.
4061·80	2—3	1	
4065·20	3—4	0	
4178·50	1—2	1	
4183·60	4	3	
4202·55	3	2—3	
4205·24	4	3	
4225·41	3	1—2	
4232·20	1—2	0	
4243·10	1	0	

"The Colour-Physiology of *Hippolyte varians*." By F. W. KEEBLE, Caius College, Cambridge, and F. W. GAMBLE, Owens College, Manchester. Communicated by Professor S. J. HICKSON, F.R.S. Received October 25,—Read November 23, 1899.

The following paper gives in a categorical fashion the chief results of a research on the changes of colour in the prawn *Hippolyte varians*. The work was carried out last year partly in the Zoological Laboratories of Owens College, Manchester, partly at the station furnished by the Lancashire Sea Fisheries Committee at Barrow; and during the past summer in M. Perrier's Laboratory at St. Vaast, Normandy. A fuller description of the experiments, together with figures, will appear shortly. The present abstract contains the following sections:—

I. Previous knowledge of colour-change in *Hippolyte varians*.
II. Methods adopted for obtaining reliable colour-records—
  a. Colour registration.
  b. Chromatophore examination.



Titanium.—Enhanced Lines.
1. Arc. 2. Spark.